PREFACE

The safety of nuclear power plant structures under the seismic loading is one of the most important design requirement A major hurdle in fulfilling this requirement lies in dealing with a significant level of uncertainty associated with the specification of the seismic load This uncertainty arises, in turn, because of the complex nature of the earthquake source mechanism, wave propagation that affect the intensity of the ground motion at a given site and the effects due to soil structure interactions The problem is further compounded by scarcity of recorded ground motions for different site conditions and focal distances For the estimation of seismic responses, the deterministic methods such as response spectrum and time history methods have been developed with certain conservative assumptions to take care of the uncertain inputs In the recent past, application of random vibration analysis techniques for the estimation of seismic responses is gaining acceptance in the nuclear industry Nevertheless, for the critical structures such as nuclear power plant components, where the responses are to be estimated with a high degree of confidence, the uncertainties associated with the seismic loading makes the design an ill posed problem The complexities are further enhanced in the case of multiply supported structures wherein a more detailed specification of the seismic loading at the supports are required Also, it is worth noting that quantification of design seismic margins in the design is currently being carried out using probabilistic methods The robustness and accuracy of such methods are open to question due to lack of available data

Under such a situation, it is valuable to know what could be the maximum possible response of a given structure The subject of critical excitation deals with this issue and offers a counterpoint to the traditional response spectrum based methods Recently a methodology for optimal random process modelling of multi-support and multi-component earthquake motions has been developed at Indian Institute of Science This method, called herein the Critical Cross Power Spectral Density (C-CPSD) method, has the potential for use in industry and therefore its performance merits a critical appraisal vis-a-vis the traditional methods of seismic response analysis Furthermore, the method, as has been developed, is inapplicable if structural nonlinearities are to be taken into account The present thesis, thus primarily aims at

1 evaluating the performance of critical seismic excitation modelling in a realistic setting and
2 contributing to the development of the methodology of critical excitations by extending the presently available procedures to nonlinear systems

The thesis is divided into five chapters and the layout of the thesis is as follows

Chapter 1 deals with a review of literature on the methods of seismic response analysis of secondary systems and the existing codes of practice It brings out the scope and limitations of the various methods and codes of practice The need to know the seismic margins available and the relevance of critical excitations in such a scenario is discussed

Chapter 2 deals with the details of a multiply supported primary discharge pipe of the 500 MWe Prototype Fast Breeder Reactor, that has been selected for the purpose of the assessment of the C-CPSD method The details of the finite element model used, results of the modal analysis and the generation of floor response spectra at support locations of the primary discharge pipe by time history and random vibration approaches are presented

A critical assessment of the C-CPSD method with respect to the estimated responses such as dynamic stresses and displacements is reported in chapter 3 by comparing the results with those estimated by the conventional methods such as multiple response spectrum method, multiple time history method and envelope spectrum method In the application of the critical excitation method, the seismic inputs are described in terms of the response spectra at the support points while the cross correlation between the support motions are taken to be unknown The unknown cross correlations are found in such a way that the response variance at any given location is maximized The results indicate that the critical excitations do not produce unduly high responses and they are about 1 3 times higher than the values that are obtained by multiple time history analysis Also, the critical excitation method clearly establishes the high degree of over conservatism associated with the envelope spectrum method In a multi-support excitation situation, as per the prevailing codes of practice, the allowable stresses for the dynamic part of the total stress is smaller than that due to the support displacements In view of this, the critical responses were obtained by maximizing the dynamic part of the total response rather than the total response Here, also, the robustness of the critical excitation method was established by changing the damage variable of interest and comparing the resulting responses over the structure The results have indicated that the overall behavior of the relative response values between any two structural points remains unchanged irrespective of the response variable with respect to which the critical excitations have been established The C-CPSD method uses a simple model for the phase characteristics between the support motions It emerges from the present study that, since the actual cross coherence in a secondary system is more complex, there is scope for improving the method by allowing for more realistic models for phase spectra

Chapter 4 considers the seismic response of a nonlinear, doubly supported, single degree of freedom system with cubic spring characteristics The two supports are subjected to stationary Gaussian support motions To start with, the support motions are taken to be completely specified An equivalent linearization based random vibration approach for analyzing the system response is developed and the scope of the method is examined using digital simulations A stochastic stability analysis of the approximate solution is also carried out to examine the validity of the equivalent linear models used Subsequently, the problem of determination of the C-CPSD function is considered and an approximate solution to this problem based on equivalent linerization is developed The numerical results demonstrate the feasibility of the proposed approach

The conclusions emerging from the above study and a few suggestions for further research are presented in the Chapter 5